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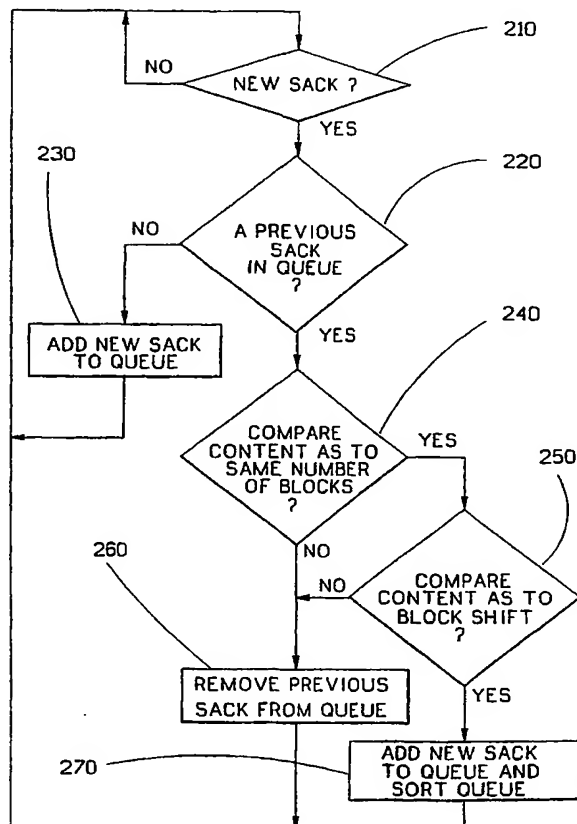
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- (75) Inventor/Applicant (for US only): **HAGGÅRD**
- (54) Title: **METHOD FOR FLOW CONTROL**
- (57) Abstract: A method of efficiently using Transmission Control Protocol (TCP) with Acknowledgements (ACKs) comprising Selective Acknowledgement (SACK) options in asymmetrical networks by reducing the number of ACKs with SACK options to be transferred back to a sender. New ACKs with SACK options are compared to previous ACKs with SACK options as to their content, and in dependence of the comparison, i.e. if the previous ACK with a SACK option comprises redundant or invalid information and no additional information in relation to the new ACK with a SACK option, then the previous ACK with the SACK option is removed and not sent back to a sender.
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## 5 Method for flow control

### TECHNICAL FIELD

10 The present invention generally relates to a method of handling asymmetrical transmissions, specifically information transported by means of transmission control protocol (TCP) via asymmetrical error prone channels.

15

### BACKGROUND

A demand for mobile high capacity data transfers have put high capacity, but unfortunately asymmetrical, wireless  
20 broadcasting transmission channels in focus. The majority of all information transfers today are made with the help of Transmission Control Protocol (TCP). Unfortunately this protocol is not designed for neither asymmetrical transmission or wireless error prone transmissions, such as  
25 Digital Audio Broadcasting (DAB), Digital Video Broadcasting Terrestrial (DVB-T), and Wavelan. Due to this there has come about many different suggestions such as replacing TCP with other modern protocols and modifying TCP to different varying degrees. For information/data  
30 transfer via wireless transfer channels special measures have to be taken to be able to manage a low as possible transmitting power. The measures can, for example, be the use of error correcting codes or special retransmission protocols.

35

To be able to handle bit errors with TCP, a Selective Acknowledgement (SACK) option to Acknowledgements (ACKs) have been developed. By means of the SACK option the TCP

transmitter can get to know which packets/segments after the first lost segment that have reached their destination. A SACK option can normally give information of up to three contiguous blocks of segments that are correctly received  
5 and also three contiguous blocks of missing or erroneous segments in the information transmission. The use of SACK options presupposes that there is no significant asymmetry in the network so that as many SACKs as information segments transmitted downlink, can be transmitted uplink.

10

One way of dealing with asymmetry in an extremely asymmetrical network is called ACK-filtering and works on the principles that many of the ACKs that are transmitted back to the transmitter are redundant and do not have to be  
15 transmitted. If there is a limitation in the return channel there will emerge a queue and it is in this queue that the ACK-filtering operates.

A combination of these two methods will create problems.  
20 SACK options are based on the assumption that there is no limitation in the return channel, and they are thus designed accordingly, and if an ACK-filtering is operated on a SACK queue, i.e. a queue of ACKs with SACK options, then some SACK blocks will be completely removed and then  
25 the transmitter will not find out that these blocks have been received. This will lead to the transmitter erroneously retransmitting the segments in these blocks that have already been received. This will result in the downlink transmission channel suffering when bandwidth is  
30 used for unnecessary retransmissions.

The problems associated with asymmetrical networks in conjunction with TCP needs to be solved satisfactorily. TCP can handle an asymmetry factor of 50 times the downlink  
35 to the uplink in most common implementations. Future

networks can have an asymmetry factor of around a 1000 times. There seems to be room for improvement.

## 5 SUMMARY

An object of the invention is to define a method for efficiently transferring information in an asymmetrical network.

10

Another object of the invention is to define a method of efficiently using TCP with ACKs comprising SACK options in an asymmetrical network.

15 The aforementioned objects are achieved according to the invention by a method of reducing the number of ACKs with SACK options to be transferred back to a sender. New ACKs with SACK options are compared to previous ACKs with SACK options as to their content, and in dependence of the  
20 comparison, i.e. if the previous ACK with a SACK option comprises redundant or invalid information and no additional information in relation to the new ACK with a SACK option, then the previous ACK with the SACK option is removed and not sent back to a sender.

25

The aforementioned objects are also achieved by a method of, when receiving information in a network that transports information according to the general principles of the Transmission Control Protocol (TCP), reducing the number of  
30 selective acknowledgements (SACKs) to be transferred back to a sender. Selective Acknowledgements, SACKs, will generally be used for referring to Acknowledgements (ACKs) with Selective Acknowledgement options. The method comprises a plurality of steps when a new selective  
35 acknowledgement has been triggered/generated. In a first

step determining if there is a previous selective acknowledgement in a queue to be transferred to the sender, and if there is a previous selective acknowledgement in the queue then further performing the following additional  
5 steps. In a first additional step comparing the content of the new selective acknowledgement with the content of the previous selective acknowledgement. Finally in a second additional step removing the previous selective acknowledgement from the queue in dependence on the result  
10 of the comparison.

Advantageously in the second additional step of removing the previous selective acknowledgement from the queue, the previous selective acknowledgement is removed from the  
15 queue if the previous selective acknowledgement has a different number of blocks than the new selective acknowledgement. Further in the second additional step of removing the previous selective acknowledgement from the queue, the previous selective acknowledgement can and/or  
20 also advantageously be removed from the queue if the previous selective acknowledgement has the same number of blocks as the new selective acknowledgement and if only the right edge of the first block is different between the previous selective acknowledgement and the new selective  
25 acknowledgement.

In some versions of the invention the method can further advantageously comprise the additional step of sorting the selective acknowledgements in the queue as to which blocks  
30 are redundant. Preferably the step of sorting comprises the following four block sorting steps. A first block sorting step of disassembling into blocks the selective acknowledgements that have not been transferred to a sender. A second block sorting step of removing redundant  
35 blocks. A third block sorting step of assembling the

remaining blocks into block sorted selective  
acknowledgements. A fourth block sorting step of placing  
the block sorted selective acknowledgements into the queue.  
The new selective acknowledgement is preferably not  
5 disassembled, but the knowledge of which blocks are  
comprised in the new selective acknowledgement is used in  
the second block sorting step for removing redundant  
blocks. In some versions there are status indicators to  
keep track of one or both of if and when a queue has been  
10 sorted with regard to selective acknowledgements.

The step of sorting can in some version of the method  
alternatively comprise the following two selective  
acknowledgement steps. A first selective acknowledgement  
15 step of comparing the selective acknowledgements that have  
not been transferred to a sender. A second selective  
acknowledgement step of removing the redundant selective  
acknowledgements, i.e. removing selective acknowledgements  
only comprising redundant blocks that are included in other  
20 selective acknowledgements.

In some versions of the method the step of sorting is  
performed only if the previous selective acknowledgement  
has not been removed from the queue.

25 Preferably the method is performed on the output queue in  
any suitable layer from the TCP layer to the link layer,  
specifically the method is performed most advantageously on  
the internet protocol layer output queue.

30 By providing a method for removing Selective  
Acknowledgements (SACKs) from an output queue a plurality  
of advantages over prior art systems are obtained. A  
primary purpose of the invention is to, in a simple manner,  
35 enable the use of highly asymmetrical networks. According

Block), have not been received. The Left Edge of a Block is the first sequence number of this block and the Right Edge of the Block is the sequence number immediately following the last sequence number of this block.

5

Following is a short example of how an ACK with a SACK option works. It is assumed that the left window edge is 5000 and that the data transmitter sends a burst of 8 segments, each containing 500 data bytes.

10

Sent	Received/ Trigger	ACK	SACK	option	blocks			
			First Left Edge	First Right Edge	Second Left Edge	Second Right Edge	Third Left Edge	Third Right Edge
5000	5000	5500						
5500								
6000	6000	5500	6000	6500				
6500								
7000	7000	5500	7000	7500	6000	6500		
7500								
8000	8000	5500	8000	8500	7000	7500	6000	6500

15

20

The first segment, 5000, is received and triggers an ACK 5500 indicating that segment 5500 is not received. The second segment, 5500, is lost, nothing further happens. The third segment, 6000, is received and triggers an ACK 5500 [ 6000 6500 ; -- ; -- ], i.e. an ACK with a SACK option. This indicates to the transmitter that the second segment is lost and by means of the SACK option that segment 6000 (bytes 6000 to 6499) has been received and not segment 6500 and further. The fourth segment, 6500, is lost, no reaction. The fifth segment, 7000, is received

25

30



and triggers an ACK 5500 [ 7000 7500 ; 6000 6500 ; -- ].  
The sixth segment, 7500, is lost, no action. The seventh  
segment, 8000, is received and triggers an ACK 5500 [ 8000  
8500 ; 7000 7500 ; 6000 6500 ].

5

SACKs presupposes that the network used for information  
transfer is fairly symmetrical, i.e. that there is no  
practical limitations in the uplink channel 170 for  
transferring SACKs back to the sender. In an asymmetrical  
10 network according to Fig. 1 an output queue 155 full of  
SACKs will form at or around the information consumer 150  
or the first uplink gate 160 due to limitations in the  
uplink channel 170. This will cause delays in the transfer  
of SACKs to the downlink gate 130 and/or the information  
15 provider 110. This in turn will also put restrictions on  
the transfer of information on the downlink channel 140,  
because there are restrictions on how much information is  
sent without any confirmation of it being received or not.  
There is thus a need to eliminate any unnecessary delays  
20 returning SACKs. According to the invention, SACKs are  
compared as to their content to determine if they can be  
discarded or not. This is preferably performed on the  
SACKs in the output queue 155.

25 When the SACKs are compared as to their content three  
different cases arise. A first case is when the new SACK  
has more blocks than the previous SACK. A second case is  
when the new SACK has fewer blocks than the previous SACK.  
Finally a third case is when the new SACK has the same  
30 number of blocks as the previous SACK.

The first case when the new SACK has more blocks than the  
previous SACK, then the previous SACK is redundant and can  
be removed. SACKs use a stack principle with push and pop  
35 where it always tries to report the latest blocks. This

means that the new SACK will comprise all of the blocks of the previous SACK and one or more new blocks. The previous SACK is thus redundant in that it does not contain any information that is not in the new SACK. For example a  
5 previous SACK has been triggered, ACK 10 [ 18 19 ; 11 17 ; -- ], segments 20 to 24 arrives triggering a new SACK, ACK 10 [ 20 25 ; 18 19 ; 11 17 ], making the previous SACK redundant.

10 The second case when the new SACK has fewer blocks than the previous SACK, then the previous SACK contains old invalid information and can be removed. Because SACKs always comprise the maximum number of blocks that is possible (in most implementations it is three blocks) this means that if  
15 the new SACK comprises fewer blocks, then new data has arrived to the receiver and filled one of the holes of data. The previous SACK thus comprises old invalid information and can be removed. For example a previous SACK is ACK 10 [ 20 25 ; 18 19 ; 11 17 ], the receiver then  
20 receives segment 19 triggering a new SACK, ACK 10 [ 18 25 ; 11 17 ; -- ], making the previous SACK redundant.

Finally a third case is when the new SACK has the same number of blocks as the previous SACK. This case needs to  
25 be divided into two different events. A first event is when new data is added to the first block. The only thing that is different between the two SACKs is that the first block is different. This means that the previous SACK comprises old invalid information and can be removed. For  
30 example a previous SACK is ACK 10 [ 20 25 ; 18 19 ; 11 17 ], the receiver receives segment 25 triggering a new SACK, ACK 10 [ 20 26 ; 18 19 ; 11 17 ], making the previous SACK redundant. A second event is when new data give rise to a new block. The new block will be put first in the SACK and  
35 push out the last block, i.e. the last block will be

shifted out and the previous SACK can thus not be removed. For example a previous SACK is ACK 10 [ 20 25 ; 18 19 ; 11 17 ], the receiver receives segment 28 triggering a new SACK, ACK 10 [ 28 29 ; 20 25 ; 18 19 ], i.e. the previous  
5 SACK comprises information about segments 11 to 17 that is not comprised in the new SACK, the previous SACK can thus not be removed.

Additionally the SACKs in an output queue can be sorted as  
10 to redundant SACKs and blocks, this is especially advantageous in the cases when a previous SACK cannot be removed. According to the invention this can be done in two different ways. In a first output queue redundancy sorting, all the blocks of the SACKs in the queue are put  
15 in a separate place/queue where all the redundant blocks are removed, whereafter new SACKs are put together with the remaining non-redundant blocks and put into the output queue. A newly triggered SACK is preferably not stripped of its blocks but only used for the determination of which  
20 blocks are redundant. In a second, and preferred, output queue redundancy sorting, the blocks of the SACKs in the output queue are compared to thus be able to remove SACKs that are completely redundant.

25 Figure 2 shows a flow chart of a method according to the invention. A first step 210 awaits the generation/triggering of a new SACK. When a new SACK has been generated to be transmitted back to a sender then the procedure determines in a second step 220 if there is any  
30 previous SACKs in an output queue which comprises SACKs to be transmitted back to the sender. If there are no SACKs in the output queue then the procedure continues with a third step 230 that simply adds the new SACK to the output queue, whereafter the procedure returns to the first step  
35 210. In the second step 220 if it is instead determined

5 FIG 1  
110 information source/provider  
120 arbitrary network such as internet  
130 gateway  
140 high speed downlink  
10 150 information consumer  
155 output queue  
160 gateway  
170 slow uplink  
180 gateway  
15  
FIG 2  
210 determine if there is a new SACK  
220 determine if there is a previous SACK in the  
output queue  
20 230 add new SACK to output queue  
240 compare content as to the same number of blocks  
250 compare content as to if there is a block shift  
260 remove previous SACK from output queue  
270 add new SACK to output queue and sort SACKs in  
25 output queue  
  
FIG 3  
310 application layer  
320 TCP layer  
30 330 IP layer  
332 IP layer output queue with SACKs  
340 PPP  
350 Ethernet  
360 output lines  
35 370 input lines

## 5 CLAIMS

1. A method of, when receiving information in a network that transports information according to the general principles of the Transmission Control Protocol (TCP),  
10 reducing the number of selective acknowledgements (SACK) to be transferred to a sender, **characterized in that** the method comprises the following steps when a new selective acknowledgement has been generated:

- 15 - determining if there is a previous selective acknowledgement in a queue to be transferred to the sender, and if there is a previous selective acknowledgement in the queue then further performing the following additional steps;
  - 20 - comparing the content of the new selective acknowledgement with the content of the previous selective acknowledgement;
  - removing the previous selective acknowledgement from the queue in dependence on the result of the comparison.

25 2. The method according to claim 1, **characterized in that** in the additional step of removing the previous selective acknowledgement from the queue, the previous selective acknowledgement is removed from the queue if the previous  
30 selective acknowledgement has a different number of blocks than the new selective acknowledgement.

3. The method according to claim 1 or 2, **characterized in that** in the additional step of removing the previous  
35 selective acknowledgement from the queue, the previous

selective acknowledgement is removed from the queue if the previous selective acknowledgement has the same number of blocks as the new selective acknowledgement and if only the right edge of the first block is different between the  
5 previous selective acknowledgement and the new selective acknowledgement.

4. The method according to any one of claims 1 to 3, characterized in that the method further comprises the  
10 additional step of:

- sorting the selective acknowledgements in the queue as to which blocks are redundant.

5. The method according to claim 4, characterized in that  
15 the step of sorting comprises the following block sorting steps:

- disassembling into blocks the selective acknowledgements that have not been transferred to a sender;
- 20 - removing redundant blocks;
- assembling the remaining blocks into block sorted selective acknowledgements;
- placing the block sorted selective acknowledgements into the queue.

25

6. The method according to claim 4, characterized in that the step of sorting comprises the following selective acknowledgement steps:

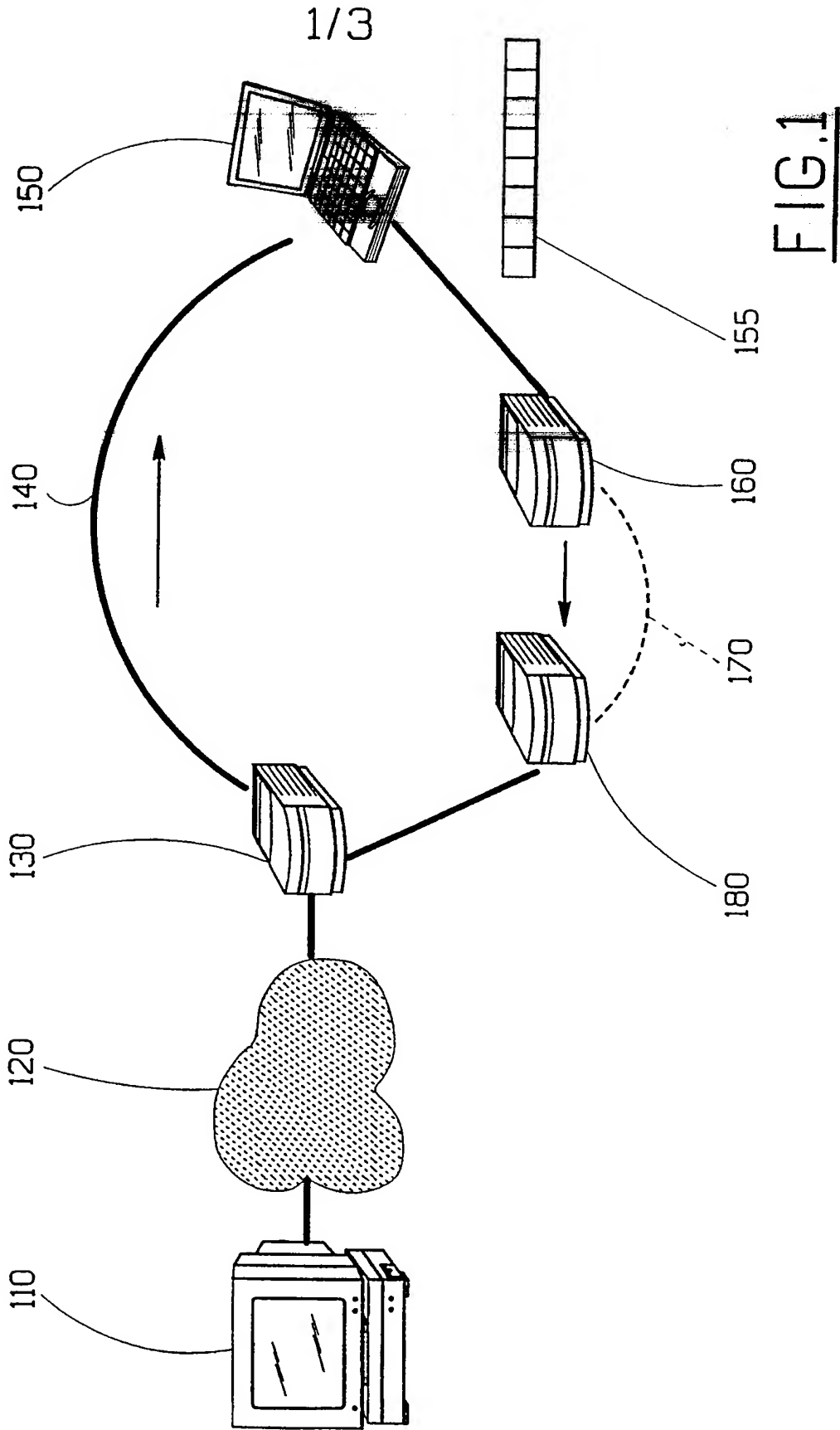
- comparing the selective acknowledgements that have not  
30 been transferred to a sender;
- removing the redundant selective acknowledgements.

7. The method according to any one of claims 4 to 6, characterized in that the step of sorting is performed only  
35 if the previous selective acknowledgement has not been

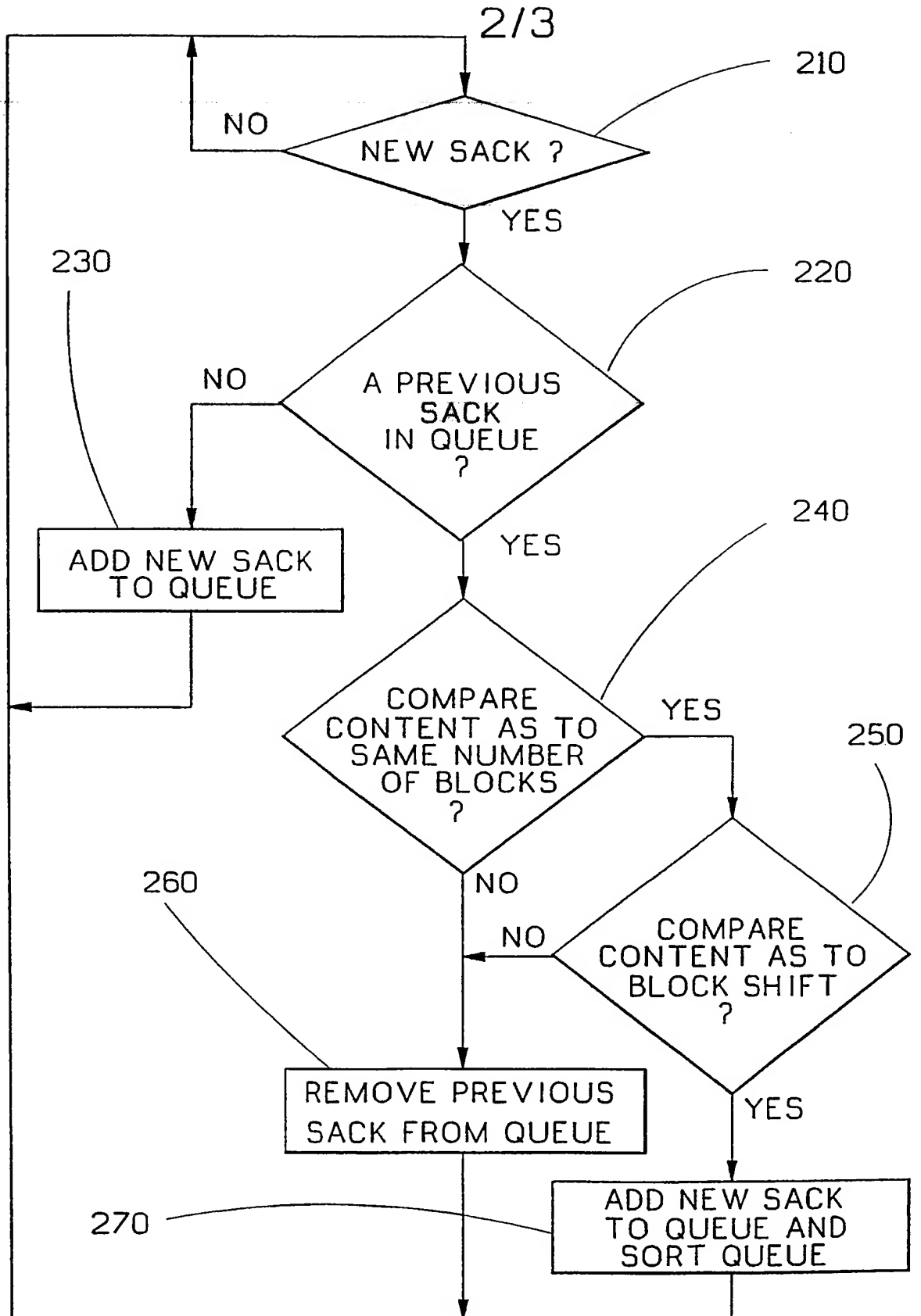
removed from the queue.

8. The method according to any one of claims 1 to 7,  
characterized in that the method is performed on a queue in  
5 any suitable layer from the TCP layer to after the link  
layer.

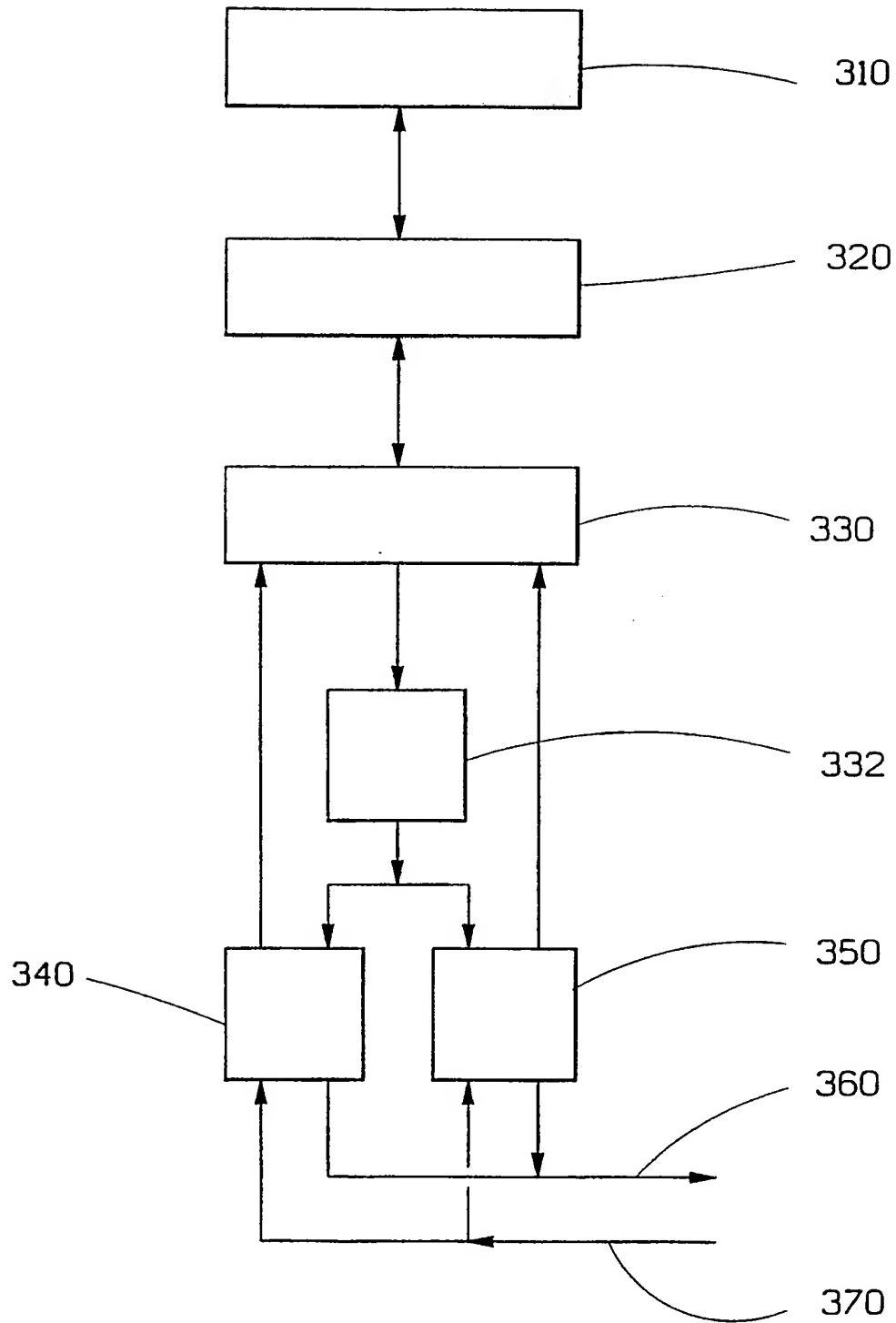
9. The method according to claim 8, characterized in that  
the method is performed on the internet protocol layer  
10 output queue.





FIG.2

3/3

FIG.3

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/SE 00/01335

## A. CLASSIFICATION OF SUBJECT MATTER

IPC7: H04Q 11/04, H04L 1/00, H04L 29/06

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: H04Q, H04L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 9837670 A1 (AT & T CORP.), 27 August 1998 (27.08.98), page 4, line 12 - page 6, line 28; page 18, line 1 - page 20, line 28, claims 1,7,8, 16-20, abstract  --	1-9
A	N.SAMARAWEEERA ET AL:"Integration of Internet Traffic with Digital Video Broadcasting"; UK Teletraffic Symposium (UKTS), IEEE, 1998. See section 4-5, abstract.  --	1-9



Further documents are listed in the continuation of Box C.



See patent family annex.

\* Special categories of cited documents:

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- "O" document referring to an oral disclosure, use, exhibition or other means
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## INTERNATIONAL SEARCH REPORT

International application No.

PCT/SE 00/01335

## C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	<p>"High Speed Internet Access Using Satellite-Based DVB Networks." International Network Conferens 199 pp23-28, Plymouth, UK  Nihal K.G. Samaraweera and Godred Fairhurst Electronics Research Group, Department of Engineering University of Aberdeen, Aberdeen, AB24 3UE, UK  Abstract, section 3.2</p> <p>--</p>	1-9
PA	<p>Internet Engineering Task Force  INTERNET DRAFT  draft-floyd-sack-00.txt  Sally Floyd, Jamshid Mahdavi, Matt Mathis, Matthew Podolsky, Allyn Romanow, August 1999  An Extension to the Selective Acknowledgement (SACK) Option for TCP  See the whole document.</p> <p>--</p>	1-9
A	<p>RFC2018  Network Working Group  Request for Comments: 2018  Category: Standards Track.  M. Mathis, J. Mahdavi, S. Floyd, LBNL, A. Romanow  Sun Microsystems October 1996.  TCP Selective Acknowledgment Options  See the whole document.</p> <p>--</p>	1-9
A	<p>GOYAL,R. ET AL: "TCP Selective Acknowledgements and UBR Drop Policies to Improve ATM-UBR Performance over Terrestrial and Satellite Networks"; Computer Communications and Networks, 22-25 September1997. Proce International Conference on; IEEE, on 16 October 2000; see pages 17 - 25</p> <p>--</p>	1-9
A	<p>GOYAL,R. ET AL:"Providing Rate Guarantees to TCP over the ATM GFR Service"; Local Computer Networks, 1998. LCN '98. Proceedings Conference on; 11 - 14 October 1998; IEEE, 16 October2000; See pages 390 - 398.</p> <p>--  -----</p>	1-9

## INTERNATIONAL-TYPE SEARCH REPORT

Search request No.

PCT/SE 00/01335

## C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	<p>Providing Rate Guarantees to TCP over the ATM GFR Service. Rohit Goyal, Raj Jain, Sonia Fahmy, Bobby Vandalore, Department of computer information science. The Ohio State University. 2015 Neil Avenue, DL 395 Columbus, OH 43210 0-8186-8810-6/98 \$10.00 8k 1997 IEEE Section 4-5, abstract</p> <p>-- -----</p>	1-9

**INTERNATIONAL-TYPE SEARCH REPORT**  
Information on patent family members

Search request No.

**PCT/SE 00/01335**

WO 9837670 A1 27/08/98 US 5974028 A 26/10/99

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